U.S. DEPARTMENT OF ENERGY

SMARTMOBILITY

Systems and Modeling for Accelerated Research in Transportation

Project ID#EEMS079
Pillar: MDS

Travel-Time Use and Value With Mobility Services

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Argonne NATIONAL LABORATORY

INL Idaho National Laboratory

BERKELEY LAB

OAK RIDGE National Laboratory

NREL NATIONAL RENEWABLE ENERGY LABORATORY

PROJECT OVERVIEW

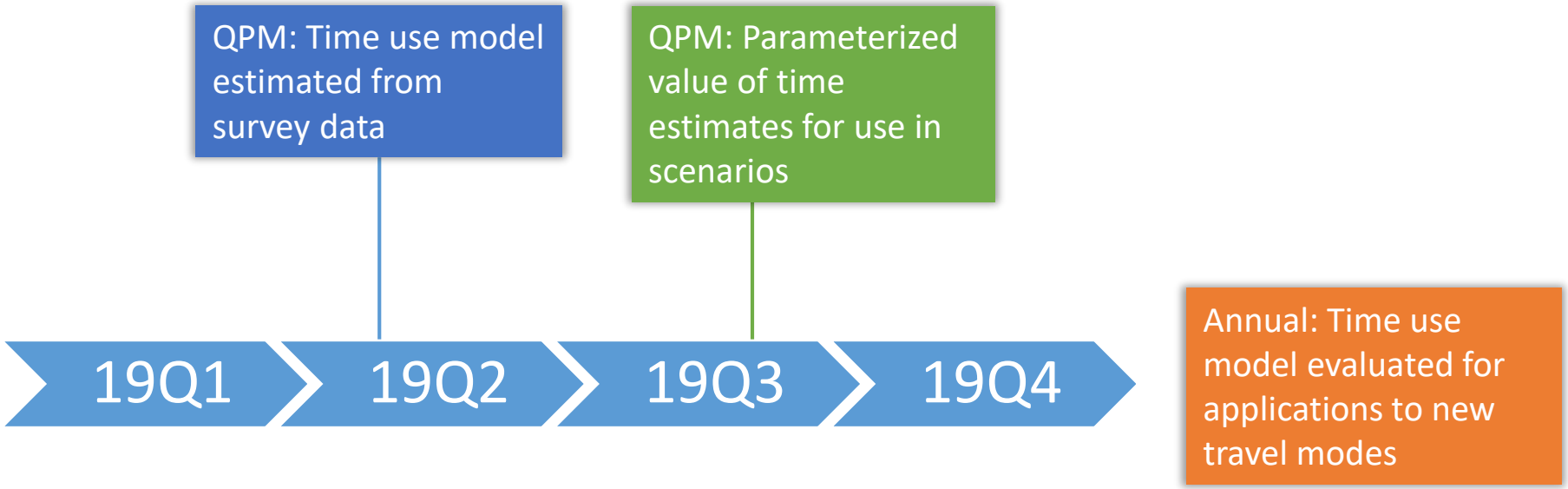
SMART MDS Task 2.1: Travel Time Use and Value with New Mobility Systems

Timeline	Barriers
• Project start date : January 2019 • Project End date : Sep. 2019 • Percent complete : 25%	• High uncertainty in technology deployment, functionality, usage, impact at system level • Lack of data on individual behaviors relating to CAV adoption and usage
Budget	**Partners**
• FY19 Funding Received : $325,000	• Argonne National Laboratory • Oak Ridge National Laboratory • University of New South Wales • University of Maine

PROJECT RELEVANCE

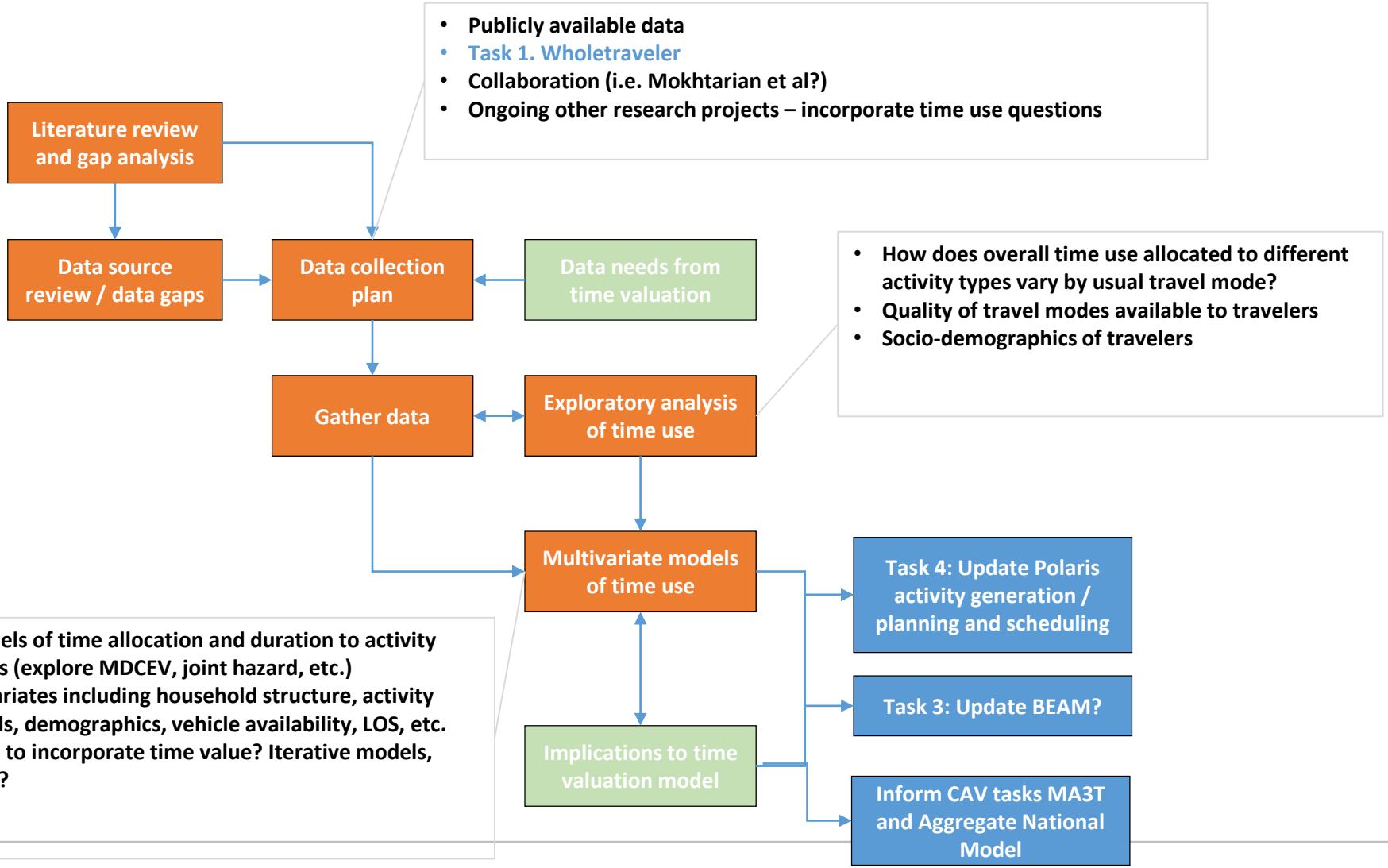
- **Objective**: determine how travel time used, how it affects non-traveling time use allocation:
  - Productive time, vs. additional discretionary time
  - Implications for time value
  - Difficult to analyze with limited data (some past studies conducted for rail)
- Multiple approaches including
  - Indirect time use estimation (from travel survey/time use):
  - Direct measured in-vehicle time use
  - Allow for exploring substitution effects, time use shifts, etc. for better input to time valuation studies
- Relevance:
  - **Update traveler behavior simulation** models including: activity generation, scheduling, and mode choice to incorporate time use and valuation effects
  - Allow extension of models to the autonomous vehicle context
  - Better understanding of **VOTT as a key unknown** in many of the forecast models

Milestones


QPM: Time use model estimated from survey data
QPM: Parameterized value of time estimates for use in scenarios
19Q1
19Q2
19Q3
19Q4
Annual: Time use model evaluated for applications to new travel modes
Task completed
In progress
On track

APPROACH

APPROACH


Publicly available data
Task 1. Wholetraveler
Collaboration (i.e. Mokhtarian et al?)
Ongoing other research projects – incorporate time use questions
Literature review and gap analysis
Data source review / data gaps
Data collection plan
Data needs from time valuation
How does overall time use allocated to different activity types vary by usual travel mode?
Quality of travel modes available to travelers
Socio-demographics of travelers
Gather data
Exploratory analysis of time use
Multivariate models of time use
Task 4: Update Polaris activity generation / planning and scheduling
Task 3: Update BEAM?
Implications to time valuation model
Inform CAV tasks MA3T and Aggregate National Model
Models of time allocation and duration to activity types (explore MDCEV, joint hazard, etc.)
Covariates including household structure, activity needs, demographics, vehicle availability, LOS, etc.
How to incorporate time value? Iterative models, SEM?

Approach: data collection, gathering and aggregation

Household Travel Surveys

CMAP, SEMCOG, ARC

- Detail information on travel arrangements and mode usage
- Limited to no information on time use (especially at home)

Time Use Surveys

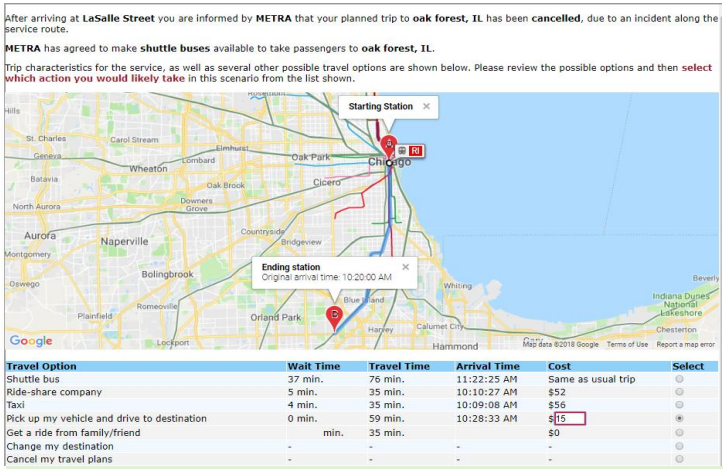
ATUS, MTUS, UKTUS

- Detailed time use information (watching TV, reading, socializing, …)
- Limited information on travel arrangements, mode usage
- Limited information on multitasking – no information on time use while traveling

New Surveys

FTA Traveler Survey, UNSW time use survey, WholeTraveler

- Includes information on travel arrangements, mode usage
- Includes information on multitasking while traveling
- Includes information on attitudes towards new mobility technologies



FTA Traveler Survey Choice Experiment

Travel mode	Privately owned AV	Taxi	Bus	Train/tram	Shared vehicle	Privately owned car	Walk or cycle
Travel type	Mandatory						
Travel time	10-20 min						
Travel cost	$5	$40	$40	$5	$5	$5	
Traffic condition	Heavy traffic	Heavy traffic	Light traffic	Free Flowing	Heavy traffic	Heavy traffic	
Crowding			Plenty of seats free and did not have to sit next to anyone	A few seats free but had to sit next to someone/could not sit with people travelling with			
Activities you engage with while traveling will help you earn money	Yes	Yes	No	No	No	No	No
Activities you engage with while traveling will help you reduce daily work load	Yes	No	No	Yes	Yes	No	No
Activities you engage with while traveling will help you reduce daily engage in other activities after work load	Yes	No	Yes	No	Yes	No	No
Activities you engage with while traveling will help you engage in other activities after work	Yes	No	No	No	No	No	No

UNSW Time Use Survey Choice Experiment

Approach: VOTT estimation Through choice modeling

Estimation using Household Travel Survey

- Uses travel tracker survey (TTS) conducted by Chicago metropolitan agency of planning (CMAP)
- Develops multiple multinomial logit models to estimate VOT for different socio demographic groups

1. $U_A = \alpha_A + \beta_{TT\text{-}A} * X_{TT\text{-}A} + \beta_{TC\text{-}A} * X_{TC\text{-}A}$
   $U_T = \alpha_T + \beta_{TT\text{-}T} * X_{TT\text{-}T} + \beta_{TC\text{-}T} * X_{TC\text{-}T} + \beta_{AT} * X_{AT} + \beta_{ET} * X_{ET};$
2. $U_A = \alpha_A + \beta_{TT\text{-}A} * X_{TT\text{-}A} + \beta_{TC\text{-}A} * X_{TC\text{-}A}$
   $U_T = \alpha_T + \beta_{TT\text{-}T} * X_{TT\text{-}T} + \beta_{TC\text{-}T} * X_{TC\text{-}T} + \beta_{AT} * X_{AT}$
3. $U_A = \alpha_A + \beta_{TT\text{-}A} * X_{TT\text{-}A} + \beta_{TC\text{-}A} * X_{TC\text{-}A}$
   $U_T = \alpha_T + \beta_{TT\text{-}T} * X_{TT\text{-}T} + \beta_{TC\text{-}T} * X_{TC\text{-}T} + \beta_{ET} * X_{ET}$
4. $U_A = \alpha_A + \beta_{TT\text{-}A} * X_{TT\text{-}A} + \beta_{TC\text{-}A} * X_{TC\text{-}A}$
   $U_T = \alpha_T + \beta_{TT\text{-}T} * X_{TT\text{-}T} + \beta_{TC\text{-}T} * X_{TC\text{-}T}$
5. $U_A = \alpha_A + \beta_{TT\text{-}A} * X_{TT\text{-}A} + \beta_{TC\text{-}A} * X_{TC\text{-}A}$
   $U_T = \alpha_T + \beta_{TT\text{-}T} * X_{IVTT\text{-}T} + \beta_{TC\text{-}T} * X_{TC\text{-}T} + \beta_{AT} * X_{AT} + \beta_{ET} * X_{ET};$
6. $U_A = \alpha_A + \beta_{TT\text{-}A} * X_{TT\text{-}A} + \beta_{TC\text{-}A} * X_{TC\text{-}A}$
   $U_T = \alpha_T + \beta_{TT\text{-}T} * X_{invTT\text{-}T} + \beta_{TC\text{-}T} * X_{TC\text{-}T} + \beta_{AT} * X_{AT} + \beta_{ET} * X_{ET};$

Estimation using Time Use Survey

- Uses ATUS, NHTS and CES data
- Studies time allocation into different activities subject to time budget constraint

$$U(x) = \sum_{k=1}^{K} \gamma_k \exp(\beta' z_k + \varepsilon_k) \ln\left(\frac{x_k}{\gamma_k} + 1\right)$$

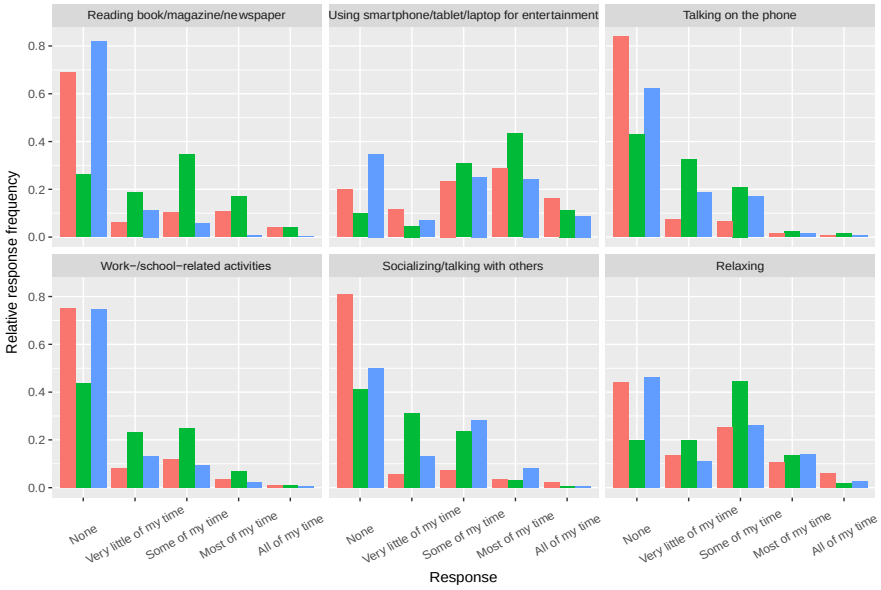
$$\sum_{k=1}^{K} x_k \leq E$$

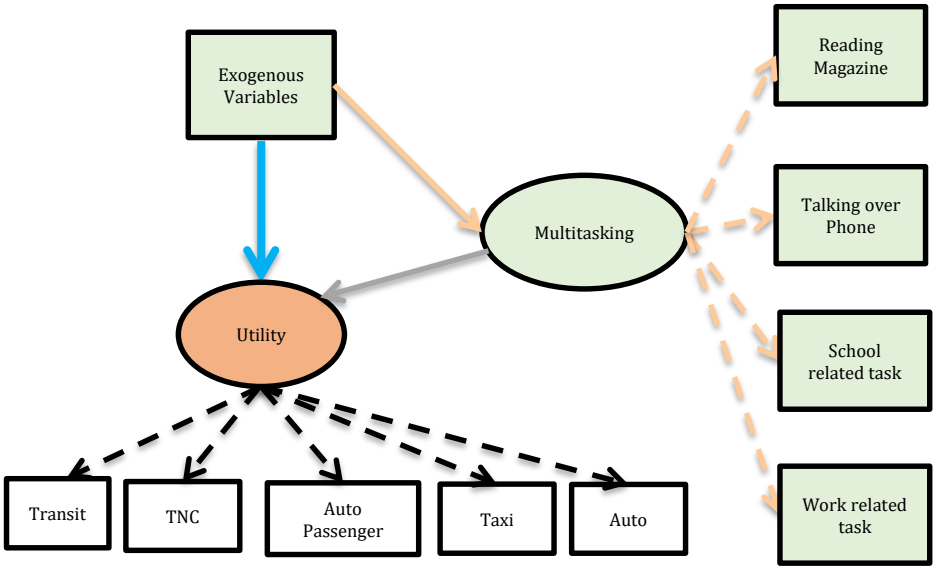
Utility of allocating time into different activity type – time allocation combination

Time budget constraint

Utility specification for different MNL models

APPROACH: TIME USE MODELING AND MULTITASKING





- Data collected from 2018 FTA transit rider survey
- Included typical time use in transit and TNC modes (general)
- Specific time use for the observed (reference) trip
- Used the data to estimate rank-ordered logit models to determine multitasking propensity while traveling

- Used integrated choice and latent variable model framework to quantify VOTT while multitasking
- Multitasking propensity estimated from ordered model is treated as latent variable
- Utilities of different modes are defined as function of multitasking propensity

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

RESULTS: CHANGE IN VOTT UNDER TRANSPORTATION SERVICE DISRUPTION

Parameter	Segment 1	Segment 2
Class Membership Model		
Sample Representation (%)	80.6	19.4
ASC	-1.7577 ***	Reference segment
Age between 25 to 34 years	0.5919 ***	
Age between 35 to 44 years	0.4708 ***	
Age above 45 years	Base	
Income up to $50K	Base	
Income between $50–100K	1.0147 ***	
Income above $100K	0.5218 ***	
Professional degree	0.8106 ***	
Use smartphone	1.1295 ***	
Choice Model		
Wait time	-1.0736 ***	-0.0138
Travel time	-0.2519 ***	-0.0829 **
Cost	-0.4266 ***	0.0113
Canceled * Wait time	0.1912 ***	0.0176
Canceled * Travel time	-0.2462 ***	0.0636
Canceled * Cost	0.0643 ***	0.0008
ASC_Shuttle/Transit	10.4562 ***	4.7801 ***
ASC_TnC	7.2183 ***	0.7334 ***
ASC_Taxi	5.9604 ***	0.1135
ASC_Pickup	-2.5148 ***	2.5344 ***
ASC_Drive	3.0492 ***	3.9661 ***
ASC_Cancel/Change	Base	Base
Sigma (σ)	3.0759 ***	2.3851 ***
WTP measures (with respect to segment 1)		
	Delays	Cancelations
VTTS (US$/hr)	17.71	41.24
Wait time / Travel time	4.27	1.78
Wait time / Cost (US$/hr)	75.67	73.27

- Wait time is penalized more for delayed trips compared to for cancelled trips
- Travel time is penalized more for cancelled trips compared to for delayed trips
- Travel cost is penalized more for delayed trips compared to for cancelled trips

- Value of travel time saving is more than two fold high for service cancellation compared to for service delay
- Value is wait time saving is 4 and 2 times higher for service and service cancellation respectively

RESULTS: MULTITASKING PROPENSITY WHILE TRAVELING

Variables	Reading book / magazine / newspaper	Use smartphone / tablet / laptop for entertainment	Talking on the phone	Work- / school-related activities	Socializing / talking with others	Time freed up
Individual-specific attributes						
Constant	-0.1524	0.3832	-1.6998***	-1.6847***	-1.7276***	-1.3330****
Female vs. male	-0.1505	-0.3134***	-0.2715	-0.4803***	-0.0815	-0.1450
Age (reference = 55 years old or older)						
18-24 years old	-1.1979***	0.8358***	-0.1981	0.4277	0.4109	0.0830
25-34 years old	-1.5042***	0.5801***	-0.1296	-0.3175	-0.1089	0.3851
35-44 years old	-1.4728***	0.4859***	-0.1344	-0.0178	-0.5072*	0.3058
45-54 years old	-0.7954***	0.2584	0.2579	-0.1090	0.1678	-0.3009
Full-time employment vs. other	0.6418***	0.3393**	-0.1786	0.3357	0.2029	-0.1858
Highest level of education is Bachelors/ graduate/ professional degree vs. other	0.1642	-0.2888*	-0.6385***	-0.1225	-0.1743	0.1616
Presence of children in household	0.1242	0.1679	0.6761***	0.4490**	0.0116	0.0810
Marital status is cohabiting/ married vs. other	0.0158	0.1911	-0.0344	0.7177***	0.4838***	0.3398*
Context-specific attributes (reference = public transit (general)						
Public transit (trip-specific)						
Constant	0.1020	0.0425	0.8078	-0.4823	1.1237*	
Type of service is rail vs. bus	0.0932	-0.0442	-0.0660	0.3185	0.0616	0.0924
Traveling alone	0.0481	0.0685	-0.1130	0.1514	-1.1152***	0.4096*
Travel time is 20 minutes or more	0.3751	-0.0290	-0.1390	0.1421	-0.3558	0.3529*
Trip includes at least one transfer	-0.0148	0.3956*	0.4321	0.1415	0.5857*	-0.1317
Departure time (reference = 10:00 AM to 2:59 PM)						
4:00 AM to 9:59 AM	0.1023	0.4317*	0.5112	0.3864	0.2551	
3:00 PM to 20:59 PM	0.0895	0.2469	0.4489	0.2581	0.4356	
Seating is available for most of the trip	0.1358	-0.1093	-0.2249	0.0875	-0.0822	0.0705
Ride-hailing (general)						
Constant	-1.8419***	-0.0552	1.0933***	-0.4803**	1.2078***	

Note:
Log-scale parameter estimates: Ranking level 2: -0.3000***; ranking level 3 or higher: -0.9737***
The activity "relaxing" is treated as a reference alternative in the rank-ordered logit model.
Log-likelihood (at convergence): -4867.30
Log-likelihood (null): -6041.77
ρ^2: 0.194
Number of parameters: 112
Significance levels: * ≤ 10%, ** ≤ 5%, *** ≤ 1%

Full time employed people tend to multitask more than others

In general female engage less in multitasking compared to male

Presence of children in the household increases multitasking propensity while traveling

RESULTS: EFFECT OF MULTITASKING ON VOTT

Structural Equation Model of Multitasking		
Exogenous Variables	*Estimates*	*Sign.*
Age	-0.332	
HH Income	8.230	*
Male Indicator	4.610	
Employment Indicator	17.200	*

* Significant at 95% level of confidence

Choice Model: Incorporating the multitasking latent		
Exogenous and Endogenous Variables	*Estimates*	*Sign.*
Constants		
Transit	1.730	*
TNC	0.822	*
Taxi	-0.045	*
Auto, passenger	-0.671	*
Auto	-1.070	*
Cancel the trip	Fixed	*
Travel cost	-0.0922	*
Travel time	-0.0192	
Wait time	-0.623	*
Latent variable in Transit: Multitasking	-0.0005	
Latent variable in TNC: Multitasking	0.0032	*

* Significant at 95% level of confidence

- Effect of demography on multitasking
  - Younger people → higher multitasking
  - High income households → higher multitasking
  - Males → higher multitasking
- Effect of multitasking on mode choice
  - People engaging in multitasking → prefer TNC
  - Participation into multitasking reduces the VOTT

RESPONSES TO PREVIOUS YEARS REVIEWERS COMMENTS

- This project was not reviewed last year

COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS

U.S. DEPARTMENT OF ENERGY SMARTMOBILITY Systems and Modeling for Accelerated Research in Transportation	EEMS011, EEMS016, EEMS017, EEMS024
UNSW SYDNEY	Value of time and time use literature review Time use analysis and value of time modeling
THE UNIVERSITY OF MAINE 1865	Data collection and analysis
BERKELEY LAB	WholeTraveler survey data collection and analysis

REMAINING CHALLENGES AND BARRIERS

- **Data limitations** Need extensive data on travel arrangements as well as on time allocation and expenditure amounts across different activities
  - Need to have time allocation information not only for the primary activity but also for simultaneous secondary activities
  - Need to infer multitasking behavior based on the current modes which might be very different from the future mobility technologies
  - Lack of familiarity with the future mobility technologies makes it challenging to collect multitasking time use information for future modes
- **Model integration** Needs integration of time use and mode choice models
  - Opportunity for multitasking is presumed to change the mode choice behavior
  - Opportunity for multitasking is also presumed the alter the activity participation and time allocation behavior
  - Changes in time allocation behavior is presumed to alter travel behavior with consequent change sin VOTT

PROPOSED FUTURE RESEARCH

- Examine how new mobility services change VOTT by learning from current modes
  - How does the (un) familiarity effect the VOTT for the new mobility services?
  - How does the multitasking opportunities offered by the new technologies change the VOTT?
- Explore how changed VOTT shape travel participation and time use:
  - What impact does it have on travel time expenditure for non-mandatory and discretionary travels?
  - Does the multitasking free up time and create opportunities for more non-mandatory/discretionary type of travel?
- How does this changed VOTT vary by person and household?
- What levers exists to change VOTT perception to improve efficiency?

Any proposed future work is subject to change based on funding levels

SUMMARY

- Value of travel time and time use behavior are identified as critical unknown parameters in modeling the impact of future mobility technologies
- Limited survey data or other behavioral data exists on VOT changes for new technologies like partial or full automation, connected vehicles, shared fleets
  - Some stated response surveys, field studies
  - Many studies of VOT under other modes and travel conditions
- We attempt to learn models of VOT changes by using analogous modes and combining multiple sources of information
- Study additional impact of new time use opportunities provided by AV on VOT
- **Key findings:**
  - Significant variation found in VOT from disparate data sources
  - Limit data on time use & multitasking during travel supplemented with new survey
  - Ability to multitask encourages use of non-drive modes & reduces VOT

QUESTIONS?